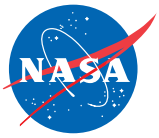
12-04 December 2004



TECH BRIEFS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

INTRODUCTION

Tech Briefs are short announcements of innovations originating from research and development activities of the National Aeronautics and Space Administration. They emphasize information considered likely to be transferable across industrial, regional, or disciplinary lines and are issued to encourage commercial application.

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Please reference the control numbers appearing at the end of each Tech Brief. Information on NASA's Commercial Technology Team, its documents, and services is also available at the same facility or on the World Wide Web at **www.nctn.hq.nasa.gov**.

Commercial Technology Offices and Patent Counsels are located at NASA field centers to provide technology-transfer access to industrial users. Inquiries can be made by contacting NASA field centers and program offices listed below.

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TECH BRIEFS

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

High-Rate Digital Receiver Board

This board converts a personal computer into a versatile telemetry-data-acquisition system.

Goddard Space Flight Center, Greenbelt, Maryland

A high-rate digital receiver (HRDR) implemented as a peripheral component interface (PCI) board has been developed as a prototype of compact, general-purpose, inexpensive, potentially mass-producible data-acquisition interfaces between telemetry systems and personal computers. The installation of this board in a personal computer together with an analog preprocessor enables the computer to function as a versatile, high-rate telemetry-data-acquisition and demodulator system. The prototype HRDR PCI board can handle data at rates as high as 600 megabits per second, in a variety of telemetry formats, transmitted by diverse phase-modulation schemes that include binary phase-shift keying and various forms of quadrature phase-shift keying. Costing less than $25,000 (as of year 2003), the prototype HRDR PCI board supplants multiple racks of older equipment that, when new, cost over $500,000. Just as the development of standard network-interface chips has contributed to the proliferation of networked computers, it is anticipated that the development of standard chips based on the HRDR could contribute to reductions in size and cost and increases in performance of telemetry systems.

The circuitry on the HRDR board includes an analog-to-digital converter (ADC) and two high-rate digital demodulator (HRDD) application-specific integrated circuits (ASICs). The HRDR board accepts a baseband radio frequency telemetry modulation signal as input. The ADC ASIC samples the input, and the sampled data is demultiplexed and sent to the two HRDD ASICs, which demodulate the signal, recover the clock and data components of the modulation, bit-synchronize the data, and serialize and forward the data to the next stage. In addition, the HRDD ASICs remove Doppler shifts from the carrier and data signals. Within each HRDD ASIC, the data are further demultiplexed by a factor of two so that the HRDD processing takes place in a total of four streams — each stream at a quarter of the incoming-data rate. Processing in multiple streams at a rate lower than the incoming-data rate makes it possible to use complementary metal oxide/semiconductor processing circuitry that is relatively inexpensive and could not perform adequately at the incoming-data rate.

The HRDR board outputs, depending on output interface setup, one or two synchronous differential emitter coupled logic (ECL) clock and data output streams. The output interface can be programmed to process and output demodulated telemetry data in multiple ways — for example, to perform CCSDS standard Viterbi decoding of convolutionally encoded data using either 3 bit soft symbols or hard symbols as inputs, interleave data I and Q channels into a single output stream, or to output each channel independently. The user can easily choose the output format by means of a simple graphical user interface.

This work was done by Parminder Ghuman, Thomas Bialas, and Clifford Brambora of **Goddard Space Flight Center** *and David Fisher of QSS Group, Inc. For further information, access the Technical Support Package (TSP)* ***free on-line at www.techbriefs.com/tsp*** *under the Electronics/Computers category. GSC-14780-1*

Signal Design for Improved Ranging Among Multiple Transceivers

Acquisition, ranging, and telemetry signals are always present.

NASA's Jet Propulsion Laboratory, Pasadena, California

"Ultra-BOC" (where "BOC" signifies "binary offset carrier") is the name of an improved generic design of microwave signals to be used by a group of spacecraft flying in formation to measure ranges and bearings among themselves and to exchange telemetry needed for these measurements. Ultra-BOC could also be applied on Earth for diverse purposes — for example, measuring relative positions of vehicles on highways for traffic-control purposes and determining the relative alignments of machines operating in mines and of construction machines and structures at construction sites. Ultra-BOC provides for rapid and robust acquisition of signals, even when signal-to-noise ratios are low. The design further provides that each spacecraft or other platform constantly strives to acquire and track the signals from the other platforms while simultaneously transmitting signals that provide full range, bearing, and telemetry service to the other platforms. In Ultra-BOC, unlike in other signal designs that have been considered for the same purposes, it is not necessary to maneuver the spacecraft or other platforms to obtain the data needed for resolving integer-carrier-cycle phase ambiguities.

A prior design provided for the broadcasting of acquisition signals, followed by rough-clock-synchronization signals, followed by ranging and telemetry signals. In contrast, in Ultra-BOC, the acquisition, ranging, and telemetry signals are always present: Ultra-BOC combines the BOC structure with constant transmission of unmodulated tones (that is, subcarrier signals) as acquisition signals, plus low-rate clock synchronization data, a pseudorandom-noise (PRN) precise-ranging code, and telemetry. A unique combination of code-division multiple access and frequency-division multiple access are employed to support simultaneous transmission and reception of these signals by many radio transceivers in the same

allocated frequency band while enabling the use of the signals for precise metrology.

The acquisition signals (unmodulated tones) do extra duty by making it possible to increase the precision of range and bearing measurements: The ranging code used in Ultra-BOC is adequate to resolve the ambiguity of a synthesized delay formed by a pair of closely-spaced unmodulated BOC tones. This delay is used to resolve the ambiguity on a more widely spaced pair of tones. This process is continued with increasingly widely spaced tones until either the range and bearing precision requirements are satisfied by use of such pairs of tones or the integer-cycle ambiguities in the phases of the carrier signals are resolved. The range measurements made in this manner can be more precise than are those that can be made by use of the PRN codes alone, because (1) the delays synthesized from pairs of tones have smaller errors attributable to system noise and (2) multipath-induced errors are the leading errors in ranging by use of PRN and the delays synthesized from pairs of tones are less susceptible to multipath-induced errors.

This work was done by Lawrence Young, Jeffrey Tien, and Jeffrey Srinivasan of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40569

Automated Analysis, Classification, and Display of Waveforms

Trends in operation of systems that generate waveforms can be spotted in real time.

John F. Kennedy Space Center, Florida

A computer program partly automates the analysis, classification, and display of waveforms represented by digital samples. In the original application for which the program was developed, the raw waveform data to be analyzed by the program are acquired from space-shuttle auxiliary power units (APUs) at a sampling rate of 100 Hz. The program could also be modified for application to other waveforms — for example, electrocardiograms.

Before this program became available, the raw APU waveforms were recorded on paper strip charts — a practice that imposed a substantial workload on human operators and was not conducive to consistently accurate, real-time analysis and classification. The program reduces the operator workload, increases the accuracy of classifications, and presents results in real time.

The program begins by performing principal-component analysis (PCA) of 50 normal-mode APU waveforms. Each waveform is segmented. A covariance matrix is formed by use of the segmented waveforms. Three eigenvectors corresponding to three principal components are calculated. To generate features, each waveform is then projected onto the eigenvectors. These features are displayed on a three-dimensional diagram, facilitating the visualization of the trend of APU operations.

It is necessary to classify each of the normal-mode waveforms as being characteristic of one of three mode types known among APU specialists as "nominal," "engine," or "aero." For this purpose, each waveform is segmented and its average energy is computed. For engine and aero modes, time information is also used, and information about peaks in the waveforms is used to determine which mode is present.

It is also necessary, when there is a malfunction, to classify waveforms as being characteristic of one or more error mode(s). To enable such classification of a waveform in real time, it is necessary to prepare the software and associated data base in a prior process that includes a careful analysis of the waveform known to be associated with each of at least five known error modes to which the APUs are subject. For each error mode, some distinct features of the waveform are extracted. Thereafter, in operation, a waveform is automatically classified as belonging to an error mode according to a few rules based on these features.

This program was written by Chiman Kwan, Roger Xu, David Mayhew, and Frank Zhang of Intelligent Automation, Inc., and Alan Zide and Jeff Bonggren of the Boeing Co. for **Kennedy Space Center**.

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Phone: (301) 294-5238
E-mail: ckwan@i-a-i.com

Refer to KSC-12568, volume and number of this NASA Tech Briefs *issue, and the page number.*

Fast-Acquisition/Weak-Signal-Tracking GPS Receiver for HEO

Goddard Space Flight Center, Greenbelt, Maryland

A report discusses the technical background and design of the Navigator Global Positioning System (GPS) receiver — a radiation-hardened receiver intended for use aboard spacecraft. Navigator is capable of weak signal acquisition and tracking as well as much faster acquisition of strong or weak signals with no *a priori* knowledge or external aiding. Weak-signal acquisition and tracking enables GPS use in high Earth orbits (HEO), and fast acquisition allows for the receiver to remain without power until needed in any orbit. Signal acquisition and signal tracking are, respectively, the processes of finding and demodulating a signal. Acquisition is the more computationally difficult process. Previous GPS receivers employ the method of sequentially searching the two-dimensional signal parameter space (code phase and Doppler). Navigator exploits properties of the Fourier transform in a massively parallel search for the GPS signal. This method results in far faster acquisition times [in the lab, 12 GPS satellites have been ac-

quired with no *a priori* knowledge in a Low-Earth-Orbit (LEO) scenario in less than one second]. Modeling has shown that Navigator will be capable of acquiring signals down to 25 dB-Hz, appropriate for HEO missions. Navigator is built using the radiation-hardened ColdFire microprocessor and housing the most computationally intense functions in dedicated field-programmable gate arrays. The high performance of the algorithm and of the receiver as a whole are made possible by optimizing computational efficiency and carefully weighing tradeoffs among the sampling rate, data format, and data-path bit width.

This work was done by Luke Winternitz, Greg Boegner, and Steve Sirotzky of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*
GSC-14793-1

Format for Interchange and Display of 3D Terrain Data

NASA's Jet Propulsion Laboratory, Pasadena, California

Visible Scalable Terrain (ViSTa) is a software format for production, interchange, and display of three-dimensional (3D) terrain data acquired by stereoscopic cameras of robotic vision systems. ViSTa is designed to support scalability of data, accuracy of displayed terrain images, and optimal utilization of computational resources. In a ViSTa file, an area of terrain is represented, at one or more levels of detail, by coordinates of isolated points and/or vertices of triangles derived from a texture map that, in turn, is derived from original terrain images. Unlike prior terrain-image software formats, ViSTa includes provisions to ensure accuracy of texture coordinates. Whereas many such formats are based on 2.5-dimensional terrain models and impose additional regularity constraints on data, ViSTa is based on a 3D model without regularity constraints. Whereas many prior formats require external data for specifying image-data coordinate systems, ViSTa provides for the inclusion of coordinate-system data within data files. ViSTa admits high-speed loading and display within a Java program. ViSTa is designed to minimize file sizes and maximize compressibility and to support straightforward reduction of resolution to reduce file size for Internet-based distribution.

This program was written by Paul Backes, Mark Powell, Marsette Vona, Jeffrey Norris, and Jack Morrison of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30600.

Program Analyzes Radar Altimeter Data

Goddard Space Flight Center, Greenbelt, Maryland

A computer program has been written to perform several analyses of radar altimeter data. The program was designed to improve on previous methods of analysis of altimeter engineering data by (1) facilitating and accelerating the analysis of large amounts of data in a more direct manner and (2) improving the ability to estimate performance of radar-altimeter instrumentation and provide data corrections. The data in question are openly available to the international scientific community and can be downloaded from anonymous file-transfer-protocol (FTP) locations that are accessible via links from altimetry Web sites. The software estimates noise in range measurements, estimates corrections for electromagnetic bias, and performs statistical analyses on various parameters for comparison of different altimeters. Whereas prior techniques used to perform similar analyses of altimeter range noise require comparison of data from repetitions of satellite ground tracks, the present software uses a high-pass filtering technique to obtain similar results from single satellite passes. Elimination of the requirement for repeat-track analysis facilitates the analysis of large amounts of satellite data to assess subtle variations in range noise.

This program was written by Doug Vandemark and David Hancock of **Goddard Space Flight Center** *and Ngan Tran of Raytheon Co. For further information, contact Nona Cheeks at Nona.K.Cheeks.1@gsfc.nasa.gov.*
GSC-14664-1

Indoor Navigation Using Direction Sensor and Beacons

Position and orientation are determined from directions to at least three beacons.

NASA's Jet Propulsion Laboratory, Pasadena, California

A system for indoor navigation of a mobile robot includes (1) modulated infrared beacons at known positions on the walls and ceiling of a room and (2) a cameralike sensor, comprising a wide-angle lens with a position-sensitive photodetector at the focal plane, mounted in a known position and orientation on the robot. The system also includes a computer running special-purpose software that processes the sensor readings to obtain the position and orientation of the robot in all six degrees of freedom in a coordinate system embedded in the room.

For a given beacon imaged on the focal plane, the output of the sensor comprises two parameters that depend in a known way on the characteristics of the lens and the direction to the beacon in a coordinate system attached to the sensor and robot. If at least three beacons are within the field of view of the sensor, then the sensor outputs from observations of all three beacons can be combined to obtain six parameters indicative of the directions to all three beacons. These directions, in combination with the known positions of the beacons, uniquely determine the position and orientation of the robot in the room. Equivalently, the six parameters constitute, in principle, sufficient data to locate the robot in all six degrees of freedom by solving the equations that express the applicable geometric relationships summarized above.

The nature of a position-sensitive photodetector is such that it is not possible to measure the centroids of two beacon images simultaneously. Therefore, it is necessary to provide for illumination of the beacons in rapid succession and to provide means for the image-data-processing software to recognize which beacon is under observation at a given instant. To satisfy this need, the beacons are turned on and off in a sequence that coincides with a predetermined code. The sensor subsystem accumulates beacon readings and their times until it begins to recognize the code sequence. Thereafter, the computer processes the readings from the recognized beacons within the field of view of the sensor.

The equations for the geometric relationships are nonlinear. The software includes a module that solves these equations by means of an iterative optimization procedure, in which it strives to find a position and orientation that, when inserted in the equations, minimizes a measure of the difference between the actual sensor readings and the sensor readings predicted by the equations.

Another software module provides an initial guess of position and orientation to start the optimization procedure. Knowing which beacons are in view, this module applies to the equations for a number of postulated robot poses and determines which pose, when inserted in the equations yields the closest match to the sensor readings. The closest match becomes the initial guess for the optimization procedure.

This work was done by Joel Shields and Muthu Jeganathan of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40730

Software Assists in Responding to Anomalous Conditions

Fault Induced Document Retrieval Officer (FIDO) is a computer program that reduces the need for a large and costly team of engineers and/or technicians to monitor the state of a spacecraft and associated ground systems and respond to anomalies. FIDO includes artificial-intelligence components that imitate the reasoning of human experts with reference to a knowledge base of rules that represent failure modes and to a database of engineering documentation. These components act together to give an unskilled operator instantaneous expert assistance and access to information that can enable resolution of most anomalies, without the need for highly paid experts. FIDO provides a system state summary (a configurable engineering summary) and documentation for diagnosis of a potentially failing component that might have caused a given error message or anomaly. FIDO also enables high-level browsing of documentation by use of an interface indexed to the particular error message. The collection of available documents includes information on operations and associated procedures, engineering problem reports, documentation of components, and engineering drawings. FIDO also affords a capability for combining information on the state of ground systems with detailed, hierarchically-organized, hypertext-enabled documentation.

This program was written by Mark James, F. Kronbert, A. Weiner, T. Morgan, B. Stroozas, F. Girouard, A. Hopkins, L. Wong, J. Kneubuhl, and R. Malina of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-40361.

Software for Autonomous Spacecraft Maneuvers

The AutoCon computer programs facilitate and accelerate the planning and execution of orbital control maneuvers of spacecraft while analyzing and resolving mission constraints. AutoCon-F is executed aboard spacecraft, enabling the spacecraft to plan and execute maneuvers autonomously; AutoCon-G is designed for use on the ground. The AutoCon programs utilize advanced techniques of artificial intelligence, including those of fuzzy logic and natural-language scripting, to resolve multiple conflicting constraints and automatically plan maneuvers. These programs can be used to satisfy requirements for missions that involve orbits around the Earth, the Moon, or any planet, and are especially useful for missions in which there are requirements for frequent maneuvers and for resolution of complex conflicting constraints. During operations, the software targets new trajectories, places and sizes maneuvers, and controls spacecraft burns. AutoCon-G provides a user-friendly graphical interface, and can be used effectively by an analyst with minimal training. AutoCon-F reduces latency and supports multiple-spacecraft and formation-flying missions. The AutoCon architecture supports distributive processing, which can be critical for formation-control missions. AutoCon is completely object-oriented and can easily be enhanced by adding new objects and events. AutoCon-F was flight demonstrated onboard GSFC's EO-1 spacecraft flying in formation with Landsat-7.

These programs were written by John Bristow, Dave Folta, Al Hawkins, and Greg Dell of **Goddard Space Flight Center**. *Further information is contained in a TSP (see page 1).*
GSC-14629-1

WinPlot

WinPlot is a powerful desktop graphical analysis tool that allows the user to generate displays of unrestrictive amounts of data. It is designed to operate on a Windows 98/NT/2000 based desktop platform. WinPlot was developed to fulfill the need for fast and easily managed graphical displays of NASA test articles and facilities with extreme amount of test data in a desktop-computer environment. WinPlot features include seamless displays of real-time and post-test-time data with time and event synchronization of data from multiple sources. WinPlot also processes full scripting capability for automation of processes. Entire analysis procedures may be recorded and replayed with a single command. Users may record their actions within WinPlot or may write scripts using text editor. Scripts may also call and execute other scripts, providing even greater automation of tasks. WinPlot is also unique in its ability to plot large volumes of data on a desktop workstation. Up to 1,000 test data files may be opened simultaneously with plots generated containing up to 1,000 curves per plot. WinPlot also has extensive abilities in generation of "on-the-fly" calculations, reducing or eliminating the need for external programs to generate the data. Calculations may include a series of recorded parameters, constants, and math functions. WinPlot's ability to export plots on a single mouse click can make easy work of preparing presentation material with office applications. One simply produces the plot with desired style and click of a button on the tool bar. Plots will be saved in a predefined folder with a sortable naming convention. One then just pastes the files into one's presentation. The ease of getting data on the screen is just the beginning with the user having many ways to manipulate data once on screen. The user can use the mouse to zoom in on any area of interest, use the arrow keys to pan around the view, or page up/down for general zooming. One may also use the mouse to select a slice of data and generate an instant report of min, max, average, range, sigma, or other values for plotted parameter within a slice. A single mouse click can export data into a spreadsheet and execute a spreadsheet application. A user may plot a parameter from a number to tests and instantly gather statistical data from the display. Importing of data from spreadsheets is as simple as copying the data to the clipboard and, within WinPlot, importing the clipboard and selecting the parameters to plot. The software package runs on a standard Windows desktop system. Memory and storage requirements are driven by the amount of data desired to be viewed and/or stored locally. Under most circumstances, the recommended system requirements for the operating system is sufficient for WinPlot. The source code modules and dynamic libraries are included in the software, which allows user versatility in importing, defining, viewing, and printing data.

This program was written by John R. Moody of Computer Sciences Corp. for **Marshall Space Flight Center**. *Further information is contained in a TSP (see page 1).*
MFS-31664

Software for Automated Testing of Mission-Control Displays

MCC Display Cert Tool is a set of software tools for automated testing of computer-terminal displays in spacecraft mission-control centers, including those of the space shuttle and the International Space Station. This software makes it possible to perform tests that are more thorough, take less time, and are less likely to lead to erroneous results, relative to tests performed manually. This software enables comparison of two sets of displays to report command and telemetry differences, generates test scripts for verifying telemetry and commands, and generates a documentary record containing display information, including version and corrective-maintenance data. At the time of reporting the information for this article, work was continuing to add a capability for validation of display parameters against a reconfiguration file.

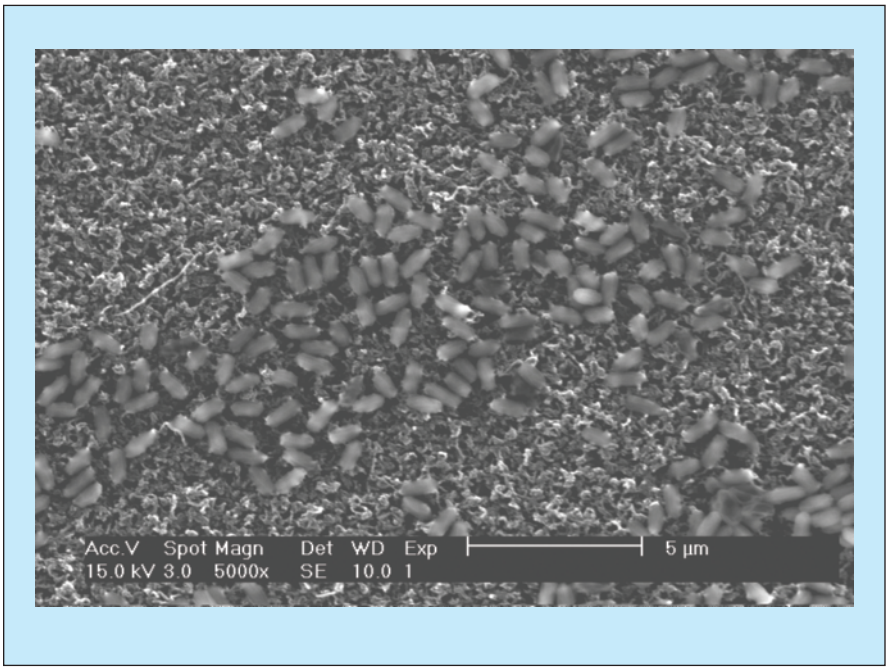
This program was written by Brian O'Hagan of **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-23573*

Nanocarpets for Trapping Microscopic Particles

Properties of nanocarpets can be tailored for selective trapping.

NASA's Jet Propulsion Laboratory, Pasadena, California

Nanocarpets — that is, carpets of carbon nanotubes — are undergoing development as means of trapping microscopic particles for scientific analysis. Examples of such particles include inorganic particles, pollen, bacteria, and spores. Nanocarpets can be characterized as scaled-down versions of ordinary macroscopic floor carpets, which trap dust and other particulate matter, albeit not purposefully. Nanocarpets can also be characterized as mimicking both the structure and the particle-trapping behavior of ciliated lung epithelia, the carbon nanotubes being analogous to cilia (see figure).



Microscopic Particles *(Bacillus pumilis spores)* were trapped on a nanocarpet by immersing the nanocarpet in a spore-containing solution, then drying the nanocarpet.

Carbon nanotubes can easily be chemically functionalized for selective trapping of specific particles of interest. One could, alternatively, use such other three-dimensionally-structured materials as aerogels and activated carbon for the purposeful trapping of microscopic particles. However, nanocarpets offer important advantages over these alternative materials:

- Nanocarpets are amenable to nonintrusive probing by optical means; and
- Nanocarpets offer greater surface-to-volume ratios.

This work was done by Flavio Noca, Fei Chen, Brian Hunt, Michael Bronikowski, Michael Hoenk, Robert Kowalczyk, and Daniel Choi of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

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Refer to NPO-30659, volume and number of this NASA Tech Briefs *issue, and the page number.*

Precious-Metal Salt Coatings for Detecting Hydrazines

Colors change upon exposure to hydrazines and perhaps other hazardous gases.

Lyndon B. Johnson Space Center, Houston, Texas

Substrates coated with a precious-metal salt $KAuCl_4$ have been found to be useful for detecting hydrazine vapors in air at and above a concentration of the order of 0.01 parts per million (ppm). Upon exposure to air containing a sufficient amount of hydrazine for a sufficient time, the coating material undergoes a visible change in color. Although the color change is only a qualitative indication, it can serve as an alarm of a hazardous concentration of hydrazine or as advice of the need for a quantitative measurement of concentration. Detection of hydrazine vapors by this technique costs much less and takes less time than does laboratory analysis of sorbent tubes using high-performance liquid chromatography, which is the technique used heretofore to detect hydrazines at concentrations down to 0.01 ppm.

A substrate for use in this technique should be made of a chemically inert material (e.g., fiberglass filter paper). The substrate is uniformly coated with 1 to 10 weight percent of the precious-metal salt in a solvent (e.g., dilute HCl) that does alter the physical characteris-

tics of the substrate. After driving off the solvent by gentle heating and/or by use of a vacuum, the coated substrate is packed into an inert tube with openings at each end. (The dried precious-metal coating is somewhat sensitive to light; the dried coated substrate should be handled accordingly and stored in the dark.)

The coated substrate is held in place with small quantities of inert wadding (i.e., borosilicate glass wool). A gas suction pump is attached to one end of the tube, and the air or other gas suspected to contain hydrazine vapor is drawn through the tube at a specified pumping rate for an amount of time sufficient to obtain a sufficient chemical change (and thus an observable color change) in the coating material. A semiquantitative relationship between the degree of chemical change and the quantity of vapor sampled can be established from observations of intensities of color changes and/or areas of color change in tests on similarly prepared substrates and tubes using known concentrations of hydrazine vapors.

In experiments, tubes containing $KAuCl_4$-coated substrates prepared as described above were exposed to 40-liter flows of air containing, variously, hydrazine, monomethylhydrazine, or unsymmetrical dimethylhydrazine at concentrations of the order of 0.01 ppm. These exposures caused the colors of the substrates to change from yellow to various purplish colors and, in one case, to black.

No such color changes were observed upon exposure of the $KAuCl_4$-coated substrates to flows of air that contained other gases (ammonia, isopropyl alcohol, NO_2, and H_2). Whether or not other precious-metal coating materials could be used as color-change indicators of these or other nonhydrazine gases remains to be determined.

This work was done by Louis A. Dee and Benjamin Greene of Allied-Signal Aerospace Co. for **Johnson Space Center**. *For further information, contact the Johnson Commercial Technology Office at (281) 483-3809.*
MSC-22870

Amplifying Electrochemical Indicators

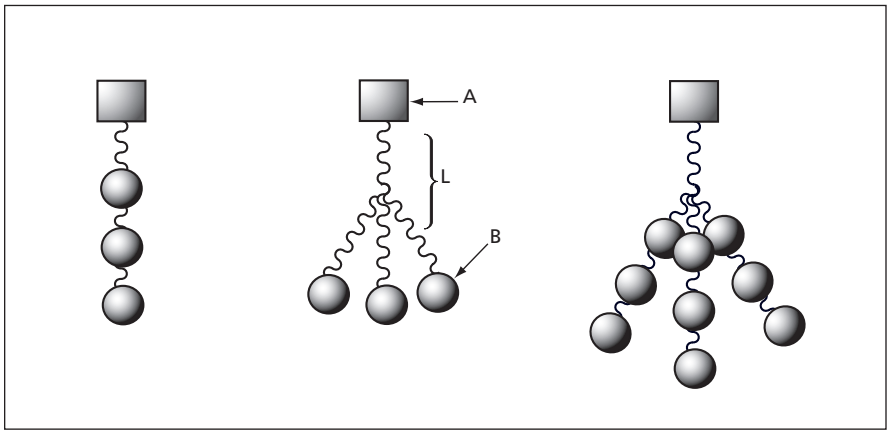
Reporter compounds can be formulated for high sensitivity and miniaturization of sensor units.

Ames Research Center, Moffett Field, California

Dendrimeric reporter compounds have been invented for use in sensing and amplifying electrochemical signals from molecular recognition events that involve many chemical and biological entities. These reporter compounds can be formulated to target specific molecules or molecular recognition events. They can also be formulated to be, variously, hydrophilic or amphiphilic so that they are suitable for use at interfaces between (1) aqueous solutions and (2) electrodes connected to external signal-processing electronic circuits. The invention of these reporter compounds is expected to enable the development of highly miniaturized, low-power-consumption, relatively inexpensive, mass-producible sensor units for diverse applications, including diagnoses of infectious and genetic diseases, testing for environmental bacterial contamination, forensic investigations, and detection of biological warfare agents.

The multiple functionality of a reporter compound of this type is achieved through integration of a variety of chemical moieties into each molecule. The structure and composition of such a molecule is depicted schematically in the figure and represented by the general formula ALB_n. As used here, A signifies a targeting group, L signifies a linking group, and B signifies an active group.

The targeting group (A) can include nucleic-acid intercalators or other organic functional subgroups. It is designed to interact directly with a targeted molecule or molecular recognition event; that is to say, it is designed to bring itself and the rest of the reporter molecule into the vicinity of the target. Hence, the collective effect of the targeting groups of multiple reporter molecules is to concentrate the reporter compound in the region of the target compound or molecular recognition events that one seeks to detect.



A **Reporter Compound** according to the invention can have any of a wide variety of dendritic structures. The A, B, and L groups contribute synergistically to the overall effect of generating a highly amplified primary electrochemical sensory signal.

An active group (B) is, more specifically, either (1) electroactive in a manner that enables detection of an electrochemical signal or (2) hydrophilic to enhance solubility. It is preferable that the number (n) of B groups exceed 1. The linking group (L) comprises two moieties: (1) a linker between the targeting (A) group and the B groups and (2) an amplifying moiety, through which the B groups are connected in series, parallel, or a combination of series and parallel connections in a dendritic structure.

The active (B) groups can also be characterized as indicator groups because these are the ones that generate the desired electronic sensory signals. Because they are linked to the targeting group, the active groups are concentrated in the vicinity of the target, and the probability that each will generate a signal is correspondingly increased. The multiple active groups, connected together in the dendritic molecular structure, contribute to an aggregate signal much greater than that generated by a single-indicator reporter molecule. Depending upon the specific formulation of a reporter molecule according the invention, the primary signal could be as little as two

times or more than a thousand times as great as that generated by a single-indicator reporter molecule. By increasing signal-to-noise ratios relative to those available from prior reporter compounds, the invention of these reporter compounds can be expected to facilitate the detection of very small amounts of target compounds — for example, particular genes in blood samples.

This work was done by Wenhong Fan, Jun Li, and Jie Han of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14908-1.

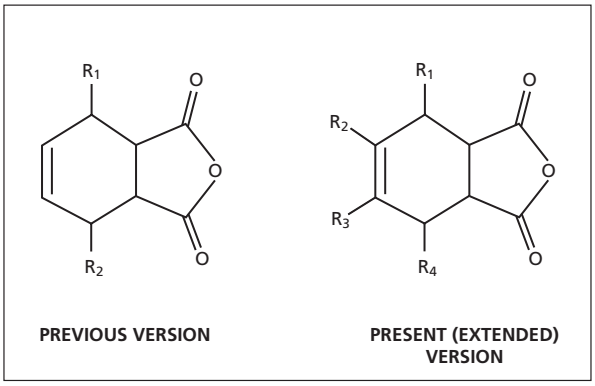
Better End-Cap Processing for Oxidation-Resistant Polyimides

Cross-linking in an inert atmosphere (as opposed to air) yields better results.

John H. Glenn Research Center, Cleveland, Ohio

A class of end-cap compounds that increase the thermo-oxidative stability of polyimides of the polymerization of monomeric reactants (PMR) type has been extended. In addition, an improved processing protocol for this class of end-cap compounds has been invented.

The class of end-cap compounds was described in "End Caps for More Thermo-Oxidative Stability in Polyimides" (LEW-17012), *NASA Tech Briefs*, Vol. 25, No. 10 (October 2001), page 32. To recapitulate: PMR polyimides are often used as matrix resins of high-temperature-resistant composite materials. These end-cap compounds are intended to supplant the norbornene end cap (NE) compound that, heretofore, has served to limit molecular weights during oligomerization and, at high temperatures, to form cross-links that become parts of stable network molecular structures. NE has been important to processability of high-temperature resins because (1) in limiting molecular weights, it enables resins to flow more readily for processing and (2) it does not give off volatile byproducts during final cure and, therefore, enables the production of void-free composite parts. However, with respect to ability of addition polymers to resist oxidation at high temperature, NE has been a "weak link." Consequently, for example, in order to enable norbornene-end-capped polyimide matrices to last for lifetimes up to 1,000 hours, it is necessary to limit their use temperatures to ≤315 °C.



End Caps of These Molecular Structures are alternatives to previously reported end caps for increasing the thermo-oxidative stability of polyimides. R1 through R4 can be any of a variety of substituents (for example, alkyl, alkoxy, aryl, halogen, or nitro), the inclusion of which reduces the cross-linking temperature.

Like NE, these end caps are also subject to oxidation at high temperatures, but they oxidize in a different manner, such that the long-term stability of a polymer made with one of these end caps exceeds the long-term stability of the corresponding polymer made with NE. Hence, use temperatures and/or lifetimes can be increased. The approach taken in formulating these end caps is to seek derivatives that preserve the desirable processing properties of NE while exploiting one of the modes of the thermo-oxidative degradation of the nadic end cap in such a way as to retard the overall thermo-oxidative degradation of the affected polymers.

The figure depicts the generic molecular structures of the prior version and the present extended version of this class of end caps. Each end cap is a 1,2,3,6-tetrahydrophthalic anhydride, substituted in such a way as to lower the cross-linking temperature. The end cap maintains its stability during imidization (at 200 °C) and cross-linking.

If the imidization is carried out in air, then the end cap subsequently aromatizes in competition with cross-linking. This aromatization is undesirable. Therefore, the improved processing protocol specifies that the process be carried out in an inert atmosphere, wherein cross-linking is the predominant, if not the exclusive, reaction path. Following cross-linking, the end cap is spontaneously converted, upon aging in air, to a thermally stable capping group.

This work was done by Mary Ann B. Meador of **Glenn Research Center** *and Aryeh A. Frimer of Bar Ilan University, Israel. Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland, Ohio 44135. Refer to LEW-17429.

Carbon-Fiber Brush Heat Exchangers

High thermal conductance between uneven surfaces could be achieved with low clamping force.

Lyndon B. Johnson Space Center, Houston, Texas

Velvetlike and brushlike pads of carbon fibers have been proposed for use as mechanically compliant, highly thermally conductive interfaces for transferring heat. A pad of this type would be formed by attaching short carbon fibers to either or both of two objects that one desires to place in thermal contact with each other.

The purpose of using a thermal-contact pad of this or any other type is to reduce the thermal resistance of an interface between a heat source (e.g., a module that contains electronic circuitry) and a heat sink (e.g., a common finned heat sink). Conventionally, to obtain high thermal conductance, a thermal interface is assembled by use of high contact pressure between faying surfaces that match each other precisely (e.g., both are precisely flat). Unfortunately, high contact pressure necessitates rigid components and strong fasteners and does not allow relative motion between the clamped parts. Compliant rubber pads or thermally conductive greases or adhesives are often used alternatively or in addition to precisely matching surfaces and high contact pressure.

The proposed carbon-fiber brush heat exchangers would offer high thermal conductance with mechanical compliance and low contact pressure, even in the case of surfaces that are uneven, do not match each other precisely, are separated by relatively wide gaps, and/or move relative to each other. In a given interface, the effective surface area of the carbon fibers could be orders of magnitude larger than the nominal footprint area of an interface.

A given thermal interface could be either single-sided (consisting of a brush on either the heat source or the heat sink) or double-sided (consisting of brushes on both the source and the sink). If the carbon fibers had high thermal conductivity and were well connected to a substrate, they would tend to isothermalize with the substrate and become thermally efficient fins. High-thermal-conductivity fibers would be well suited for brush heat exchangers because they are straight, are available in small diameters, and are compatible with many materials, even at high temperatures.

Double-sided carbon-fiber brush heat exchangers would be related to interleaving metal-fin heat exchangers, but for a given footprint area, the carbon-fiber brush heat exchangers would have larger radiating surface areas and would weigh less. The high thermal conductances occasioned by the use of carbon-fiber brush heat exchangers could be utilized to decrease the sizes and weights of heat sinks (including radiators) for a given heat-dissipation rate, increase heat-dissipation rates for heat sinks of a given size and weight, and/or enable heat-generating equipment to operate at lower temperatures. The elimination of the need for structures to resist large thermal-interface clamping forces would enable further weight reductions.

This work was done by Timothy R. Knowles of Energy Science Laboratories, Inc., for **Johnson Space Center.** *For further information, contact the Johnson Commercial Technology Office at (281) 483-3809. MSC-23018*

Solar-Powered Airplane With Cameras and WLAN

High-resolution images are sent to a ground station in nearly real time.

Ames Research Center, Moffett Field, California

An experimental airborne remote-sensing system includes a remotely controlled, lightweight, solar-powered airplane (see figure) that carries two digital-output electronic cameras and communicates with a nearby ground control and monitoring station via a wireless local-area network (WLAN). The speed of the airplane — typically <50 km/h — is low enough to enable loitering over farm fields, disaster scenes, or other areas of interest to collect high-resolution digital imagery that could be delivered to end users (e.g., farm managers or disaster-relief coordinators) in nearly real time.

In addition to achieving the desired flight, remote-sensing, remote-control, and remote-monitoring capabilities, one of the goals in the development of this system has been minimizing its cost through the use of commercial off-the-shelf hardware and software. Accordingly, the mention of brand names in the following description of the system does not constitute an endorsement and is not intended to exclude hardware and software of different brand names that afford equivalent capabilities.

One of the camera systems — for acquiring high-resolution red/green/blue images — includes a Hasselblad 555ELD camera body assembled with a Kodak Professional DCS Pro Back 4,000-by-4,000-pixel charge-coupled-device (CCD) array and a color filter array. The other system — for imaging in three narrow wavelength bands — comprises a DuncanTech MS3100 camera with a single Nikon 35-mm lens, which, in combination with a dichroic prism, focuses incoming light through three separate narrow-band filters onto three 1,280-by-1,024-pixel CCD arrays. The three wavelength bands are 760±20, 660±10, and 580±10 nm.

The WLAN is implemented by use of Cisco Aironet 340-series Ethernet bridges, which operate at frequencies between 2.4 and 2.5 GHz. These bridges are capable of functioning as bidirectional, line-of-sight, high-speed data links between two or more networks (in this case, an airborne and a ground-based network). These bridges were originally designed as building-to-building links but are advertised as being ca-

A **Solar-Powered, Unpiloted Airplane** includes two payload pods, on the underside of the middle section, that carry electronic cameras and telemetry subsystems.

pable of data rates of 11 Mb/s over distances up to 40 km. The WLAN is configured for remote control of the camera and transmission of acquired imagery to the ground station. A bridge in the airborne network serves as the link between an airborne system payload computer and an omnidirectional stub antenna on the underside of the airplane. A bridge in the ground station serves as a link between the ground antenna and a laptop computer. The remote-control software is installed in both the system payload computer and the portable laptop computer. The ground-based payload operator controls each camera remotely by use of the laptop computer.

Testing and development of the system were continuing at the time of reporting the information for this article. Particularly notable is a flight test, performed in September 2002, to demonstrate safe and effective operation of the system in an agricultural setting in FAA controlled airspace. The airplane was flown for four hours over a 15-km^2 coffee plantation in Hawaii, under supervision by Honolulu air-traffic controllers as though it were a conventionally piloted aircraft. The airplane was shown to be capable of flying planned routes and to perform spontaneous maneuvers to collect imagery in cloud-free areas. The WLAN was capable of downloading image data at rates exceeding 5 Mb/s, making all image data available for viewing, enhancing, and printing within a few minutes of collection. During the latter part of the flight, the payload was operated over an established wide-area network by an operator located on the United States mainland at a distance of 4,000 km.

This work was done by Robert G. Higgins, Steve E. Dunagan, Don Sullivan, Robert Slye, and James Brass of **Ames Research Center***; Joe G. Leung, Bruce Gallmeyer, Michio Aoyagi, and Mei Y. Wei of Dryden Flight Research Center; Stanley R. Herwitz of Clark University; Lee Johnson and Jian Zheng of California State University; and John C. Arvesen of Kauai Airborne Sciences. Further information is contained in a TSP (see page 1).*
ARC-15061

A Resonator for Low-Threshold Frequency Conversion

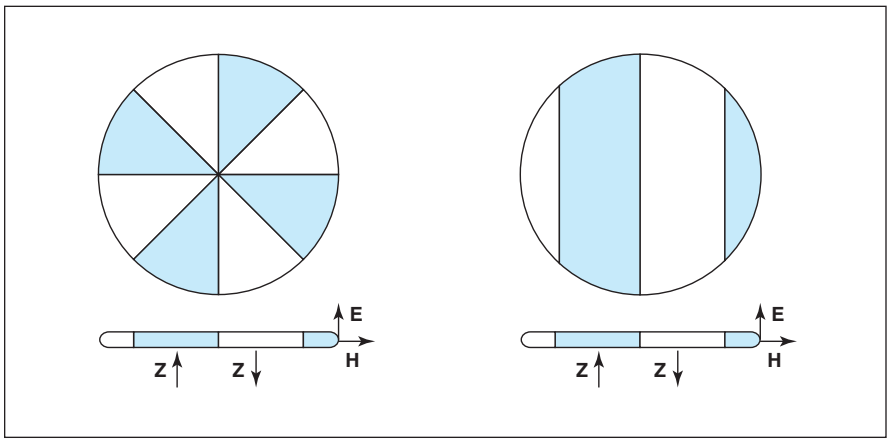
A nonlinear dielectric whispering-gallery resonator would be poled for quasi-phase-matching.

NASA's Jet Propulsion Laboratory, Pasadena, California

A proposed toroidal or disklike dielectric optical resonator (dielectric optical cavity) would be made of an optically nonlinear material and would be optimized for use in parametric frequency conversion by imposition of a spatially periodic permanent electric polarization. The poling (see figure) would suppress dispersions caused by both the material and the geometry of the optical cavity, thereby effecting quasi-matching of the phases of high-resonance-quality (high-*Q*) whispering-gallery electromagnetic modes. The quasi-phase-matching of the modes would serve to maximize the interactions among them. Such a resonator might be a prototype of a family of compact, efficient nonlinear devices for operation over a broad range of optical wavelengths.

A little background information is prerequisite to a meaningful description of this proposal:

- Described in several prior *NASA Tech Briefs* articles, the whispering-gallery modes in a component of spheroidal, disklike, or toroidal shape are waveguide modes that propagate circumferentially and are concentrated in a narrow toroidal region centered on the equatorial plane and located near the outermost edge.
- For the sake of completeness, it must be stated that even though optical resonators of the type considered here are solid dielectric objects and light is confined within them by total internal reflection at dielectric interfaces without need for mirrors, such components are sometimes traditionally called cavities because their effects upon the light propagating within them are similar to those of true cavities bounded by mirrors.
- For a given set of electromagnetic modes interacting with each other in an optically nonlinear material (e.g., modes associated with the frequencies involved in a frequency-conversion scheme), the threshold power for oscillation depends on the mode volumes and the mode-overlap integral.
- Whispering-gallery modes are attractive in nonlinear optics because they maximize the effects of nonlinearities by occupying small volumes and affording high *Q* values.



A **Disk of $LiNbO_3$** or perhaps another suitable optically nonlinear material would be poled periodically, possibly in one of these two patterns. The labels **E** and **H** denote the electric and magnetic field axes, respectively, of a whispering-gallery electromagnetic field. The labels **Z** denote the vectors of permanent electric polarization.

In designing a cavity according to the proposal, one could reduce the mode volume and increase the mode-overlap integral, and thereby reduce the threshold power needed for oscillation, relative to those of a the nonlinear material in bulk form. The amplitude, configuration, and periodicity of the poling would be chosen so that the whispering-gallery modes to be quasi-phased-matched were the modes associated with the pump, signal, and idler frequencies involved in the parametric frequency conversion. It would be necessary to perform some complex computations, including calculation of quantum-mechanical mode

wave functions and evaluation of mode-overlap integrals, in order to analyze the performance of the cavity and design it for quasi-phase-matching.

The nonlinear cavity material would likely be commercially available flat, *Z*-cut $LiNbO_3$. The optimum poling geometry would be the one symmetrical about the center, shown on the left side of the figure. However, the imposition of centrally symmetric poling would be difficult. It would be much easier to use a slice of $LiNbO_3$ as supplied commercially with poling stripes; this would entail an increase in the threshold power for oscillation, relative to the optimum symmetrical poling pattern. On the other hand, the striped poling would enable the parametric generation of oscillations at multiple frequencies.

This work was done by Vladimir Iltchenko, Andrey Matsko, Anatoliy Savchenkov, and Lute Maleki of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

In accordance with Public Law 96-517, the contractor has elected to retain title to this invention. Inquiries concerning rights for its commercial use should be addressed to:

Innovative Technology Assets Management
JPL
Mail Stop 202-233
4800 Oak Grove Drive
Pasadena, CA 91109-8099
(818) 354-2240
E-mail: iaoffice@jpl.nasa.gov

Refer to NPO-30638, volume and number of this NASA Tech Briefs *issue, and the page number.*

Masked Proportional Routing

This procedure enables adaptation to changing network conditions.

Ames Research Center, Moffett Field, California

Masked proportional routing is an improved procedure for choosing links between adjacent nodes of a network for the purpose of transporting an entity from a source node ("A") to a destination node ("B"). The entity could be, for example, a physical object to be shipped, in which case the nodes would represent waypoints and the links would represent roads or other paths between waypoints. For another example, the entity could be a message or packet of data to be transmitted from A to B, in which case the nodes could be computer-controlled switching stations and the links could be communication channels between the stations. In yet another example, an entity could represent a workpiece while links and nodes could represent, respectively, manufacturing processes and stages in the progress of the workpiece towards a finished product. More generally, the nodes could represent states of an entity and the links could represent allowed transitions of the entity.

The purpose of masked proportional routing and of related prior routing procedures is to schedule transitions of entities from their initial states ("A") to their final states ("B") in such a manner as to minimize a cost or to attain some other measure of optimality or efficiency. Masked proportional routing follows a distributed (in the sense of decentralized) approach to probabilistically or deterministically choosing the links. It was developed to satisfy a need for a routing procedure that

1. Does not always choose the same link(s), even for two instances characterized by identical estimated values of associated cost functions;
2. Enables a graceful transition from one set of links to another set of links as the circumstances of operation of the network change over time;
3. Is preferably amenable to separate optimization of different portions of the network;
4. Is preferably usable in a network in which some of the routing decisions are made by one or more other procedure(s);
5. Preferably does not cause an entity to visit the same node twice; and
6. Preferably can be modified so that separate entities moving from A to B do not arrive out of order.

Definitions of several terms are prerequisite to even a brief summary of the mathematical nature of masked proportional routing. Consider a network of N nodes ($N \geq 2$) including a source node A and destination node B (see figure). Node i is directly connected to an arbitrary number $J(\mu)$ of nodes, which are labeled $j = j_1, j_2, ..., j_{J(\mu)}$. The term μ represents a characteristic or a set of characteristics of an entity that one seeks to transport from node i to one of the connected nodes j along the route from A to B. The characteristics represented by μ could include the source and/or destination node(s), the routing priority, and/or the time elapsed since leaving the source node. Associated with node i is a $J(\mu)$-component vector, denoted a baseline proportion vector, $\mathbf{p}(i;\mu)$.

In a deterministic version of masked proportional routing, $\mathbf{p}(i;\mu)$ is used to compute a $J(\mu)$-component vector, denoted an applied proportion vector, $\mathbf{p}^*(i;\mu)$, that prevents the entity from visiting the same node more than once. In this case, if k is a node that has already been visited, then the jth component of $\mathbf{p}^*(i;\mu)$ is made zero; that is, $\mathbf{p}^*(i;\mu)_k = 0$.

In another version of masked proportional routing, there are computed (as described below) two other $J(\mu)$-component vectors, denoted $\text{Target}(i;n(\mu);\mu)$ and $\text{Actual}(i;n(\mu);\mu)$, where $n(\mu)$ is a sequence number or a count at node i that may depend on one or more component(s) of μ. Except as described in the last sentence of this paragraph, the link from node i to node $j'(\mu)$ is selected as being the one that yields the largest difference between $\text{Target}(i;n(\mu);\mu)$ and $\text{Actual}(i;n(\mu);\mu)$. The entity is then transported along the i-to-$j'(\mu)$ link. The vectors $\text{Target}(i;n(\mu);\mu)$ and $\text{Actual}(i;n(\mu);\mu)$ are computed iteratively as follows:

$$\text{Target}(i;n(\mu);\mu) = \alpha(\mu)\text{Target}(i;n(\mu)-1;\mu) + \beta(\mu)\mathbf{p}^*(i;\mu)$$

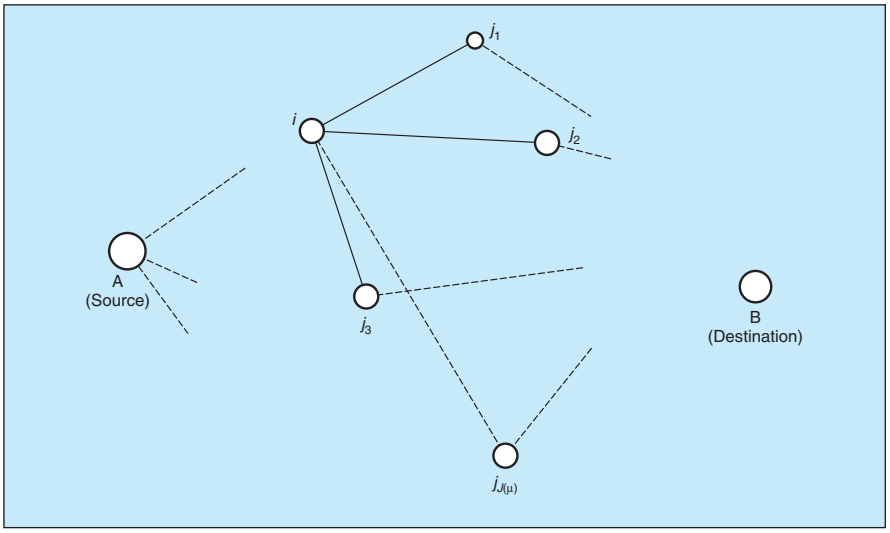
and

$$\text{Actual}(i;n(\mu)+1;\mu) = \alpha(\mu)\text{Actual}(i;n(\mu);\mu) + \beta(\mu)\text{Sent}(i;j'(\mu);n(\mu);\mu),$$

where $\alpha(\mu)$ and $\beta(\mu)$ are selected real numbers and $\text{Sent}(i;j'(\mu);n(\mu);\mu)$ is a $J(\mu)$-component vector, the $j'(\mu)$th component of which is 1 and all other components of which are 0. The exception mentioned above applies in special circumstances in which the same link is optionally used to transport consecutively arriving entities.

This work was done by David Wolpert of **Ames Research Center**. *Further information is contained in a TSP (see page 1).*

Inquiries concerning rights for the commercial use of this invention should be addressed to the Patent Counsel, Ames Research Center, (650) 604-5104. Refer to ARC-14366-1.



An **Entity Is Transported** from node A via network links to node B.

Algorithm Determines Wind Speed and Direction From Venturi-Sensor Data

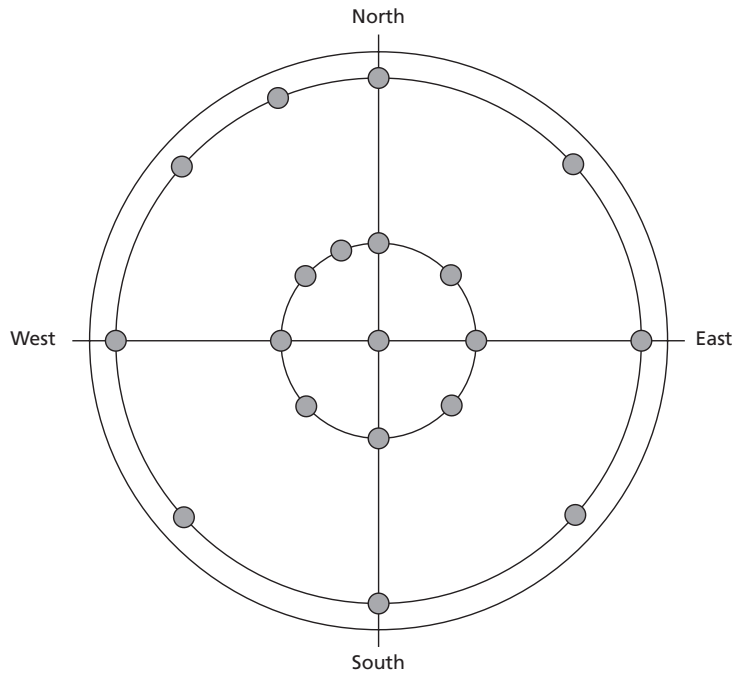
Speed and direction are calculated from the spatial distribution of pressure readings.

John F. Kennedy Space Center, Florida

An algorithm computes the velocity of wind from the readings of an instrument like the one described in "Three-Dimensional Venturi Sensor for Measuring Extreme Winds" (KSC-12435), *NASA Tech Briefs*, Vol. 27, No. 9 (September 2003), page 32. To recapitulate: The sensor has no moving parts and is a compact, rugged means of measuring wind vectors having magnitudes of as much as 300 mph (134 m/s). The sensor includes a Venturi gap bounded by a curved upper and a curved lower surface that are axisymmetric with respect to a vertical axis and mirror-symmetric with respect to a horizontal midplane. One of the curved surfaces is instrumented with multiple ports for measuring dynamic pressures (see figure). The sensor also incorporates auxiliary sensors for measuring temperature, relative humidity, and static atmospheric pressure.

The design and operation of the sensor are based on the concepts of (1) using Bernoulli's equation (which expresses the relationship among variations of speed, density, and pressure along a streamline) to calculate the speed of the wind from differences among the pressure readings at the various ports; and (2) calculating the direction of the wind from the angular positions of ports selected according to comparisons among their pressure readings. The present algorithm performs these calculations. Although the algorithm is much too complex to describe here in detail, it is worthwhile to expand on the major underlying physical and mathematical concepts:

- The auxiliary measurements of temperature and relative humidity are used, along with the measurement of static pressure, to calculate the density of air for use in Bernoulli's equation.
- The pressure at the central port on the Venturi surface is always the lowest and is directly related to static pressure and the wind speed by Bernoulli's equation.
- The pressure readings from all the Venturi ports except the central one depend on both the speed and direction of the wind. Some convey more information about speed, while some convey more information about direction. The algorithm combines information from all the readings to resolve uncertainties in calculating the speed and direction.
- Pressures at upwind ports are greater than those at the central and downwind ports. Pressures are lowest at ports located at angular positions orthogonal to the wind. These directional characteristics are utilized to calculate the wind direction to within an angular interval of 45° for the pressure-port arrangement shown in the figure.
- The wind direction can be estimated more accurately by means of a polynomial interpolation from the real pressure readings to a fictitious set of pressure readings at ports in a rotated version of the real pattern of ports.



Pressure Ports at Multiple Locations on a Venturi surface provide samples of the spatial distribution of pressure, which distribution is directly related to the speed and direction of the wind.

This work was done by Jan A. Zysko and Jose M. Perotti of **Kennedy Space Center** *and John Randazzo of Dynacs, Inc. Further information is contained in a TSP (see page 1).*
KSC-12516

Feature-Identification and Data-Compression Software

NASA's Jet Propulsion Laboratory, Pasadena, California

A report discusses the continuing development of Windows Interface for Nominal Displacement Selection (WINDS), a computer program for automated analysis of images of the Sun and planets acquired by scientific instruments aboard spacecraft. WINDS is intended to afford capabilities for identification of features, measurement of displacements and velocities, analysis of terrain and of atmospheres, and synthesis of animation sequences of images of terrains and atmospheres from small sets of samples by use of velocity-based interpolation. A major element of WINDS will be a nonlinear correlator capable of tracking small features in complex image sequences. For dynamic image sequences, the correlator will enable compression of data by factors >100. In processing image data, WINDS will take account of such factors as texture in image data, rotation of features during measurement intervals, effects of viewing and solar illumination angles, and vertical structures of atmospheres. WINDS will also take account of positions, aiming directions, and fields of view of cameras to determine three-dimensional feature structures by use of triangulation and stereoscopic analysis techniques.

This work was done by Eric De Jong and Jean Lorre of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*

This software is available for commercial licensing. Please contact Don Hart of the California Institute of Technology at (818) 393-3425. Refer to NPO-30360.

Books & Reports

Alternative Attitude Commanding and Control for Precise Spacecraft Landing

A report proposes an alternative method of control for precision landing on a remote planet. In the traditional method, the attitude of a spacecraft is required to track a commanded translational acceleration vector, which is generated at each time step by solving a two-point boundary value problem. No requirement of continuity is imposed on the acceleration. The translational acceleration does not necessarily vary smoothly. Tracking of a non-smooth acceleration causes the vehicle attitude to exhibit undesirable transients and poor pointing stability behavior. In the alternative method, the two-point boundary value problem is not solved at each time step. A smooth reference position profile is computed. The profile is recomputed only when the control errors get sufficiently large. The nominal attitude is still required to track the smooth reference acceleration command. A steering logic is proposed that controls the position and velocity errors about the reference profile by perturbing the attitude slightly about the nominal attitude. The overall pointing behavior is therefore smooth, greatly reducing the degree of pointing instability.

This work was done by Gurkirpal Singh of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-40585

Inspecting Friction Stir Welding Using Electromagnetic Probes

A report describes the use of advanced electromagnetic probes to measure the dimensions, the spatial distribution of electrical conductivity, and related other properties of friction stir welds (FSWs) between parts made of the same or different aluminum alloy(s). The probes are of the type described in "Advanced Electromagnetic Probes for Characterizing Materials" (GSC-13878), *NASA Tech Briefs*, Vol. 21, No. 11 (November 1997), page 4a. To recapitulate: A probe of this type is essentially an eddy-current probe that includes a primary (driver) winding that meanders and multiple secondary (sensing) windings that meander along the primary winding. Electrical conductivity is commonly used as a measure of heat treatment and tempering of aluminum alloys, but prior to the development of these probes, the inadequate sensitivity and limited accuracy of electrical-conductivity probes precluded such use on FSWs between different aluminum alloys, and the resolution of those probes was inadequate for measurement of FSW dimensions with positions and metallurgical properties. In contrast, the present probes afford adequate accuracy and spatial resolution for the purposes of measuring the dimensions of FSW welds and correlating spatially varying electrical conductivities with metallurgical properties, including surface defects.

This work was done by David G. Kinchen of Lockheed Martin Corp. for **Marshall Space Flight Center**. *For further information contact Gary Willett at (504) 257-4786.*

Title to this invention has been waived under the provisions of the National Aeronautics and Space Act [42 USC 2457 (f)] to Lockheed Martin Space Systems Company — Michoud Operations. Inquiries concerning licenses for its commercial development should be addressed to:

Lockheed Martin Michoud Space Systems
P.O. Box 29304
New Orleans, LA 70189.

Refer to MFS-31979, volume and number of this NASA Tech Briefs *issue, and the page number.*

Helicity in Supercritical O_2/H_2 and C_7H_{16}/N_2 Mixing Layers

This report describes a study of databases produced by direct numerical simulation of mixing layers developing between opposing flows of two fluids under supercritical conditions, the purpose of the study being to elucidate chemical-species-specific aspects of turbulence, with emphasis on helicity. The simulations were performed for two different fluid pairs —O_2/H_2 and C_7H_{16}/N_2 — at similar values of reduced pressure.

This work was done by Nora Okong'o and Josette Bellan of Caltech for **NASA's Jet Propulsion Laboratory**. *Further information is contained in a TSP (see page 1).*
NPO-30894


NASA
National Aeronautics and
Space Administration